NISA PRESENTATION*

HOPPER SCALE FIELD TEST

The testing of hopper scales seems to intimidate many field inspectors. They dread the task of doing a substitution test or a strain load test; there is often confusion about the difference between the two types of tests, how the error is determined at the various test points, and how the tolerances are to be applied. I intend to explain those tests in a manner that will alleviate some of those apprehensions. While there are obstacles to be overcome, such as having the appropriate amount of known test weight readily available and having an easy method for applying that test load, the mechanics of the actual test procedure are, in reality, not much more difficult than a properly executed test of a large vehicle scale. The key is in having the right equipment for the test, understanding the tests to be performed, and understanding how to interpret the results of the tests.

I will start my presentation* with a list of equipment that may be necessary for the average hopper scale test. Then I will explain a few terms and types of tests that, while not unique to hopper scales, are more frequently associated with that type of inspection. Finally, I will outline the tests to be performed, including the application of weights, the calculation of the tolerances, and the determination of errors. For the purpose of this discussion I am going to assume that we are testing a scale we have not tested--nor even seen--previous to the request for inspection.

Equipment.
In order to know what equipment is necessary to conduct a proper test, you need to know something about the scale in advance of the test. An on-site visit prior to the scheduled test date is the best way to determine the necessary equipment for an appropriate test. Sometimes an on-site visit is not practical or even possible. In that case, phone conversations with all of the parties to be involved in the test may be the next best option; this may include the testing official, the scale service agency, and representatives of the scale owner.

Initial questions to address are: What is the capacity and division size? Is it full electronic, mechanical, or electromechanical? Once the capacity has been determined the following questions are very important: Can at least 25 percent of that capacity be applied in known test weights? What size of test weights can be used? Are the test weights already in place (i.e., permanently at the scale)? If they are not in place, what is required to get the appropriate weights to the load-receiving element? If the weights are in place, do they have a current laboratory certification?

Once these questions have been addressed, the inspector must determine how the weights will be applied to the scale. The method of applying known test weights often presents the greatest challenge for the test. I am sure that many of you have been involved in the testing of a large capacity hopper scale using only fifty-pound test weights. Doing

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substitution testing of a hopper with as much as 10 000 lb in fifty-pound weights becomes very labor intensive, time consuming, and sometimes downright dangerous.
I was involved in one test that required stacking 10 000 lb of fifty-pound weights on a bridge plank suspended from two chains on one side of the scale, and only one side was accessible. During the third time of stacking the weights on the plank, at more than 9 000 lb, the plank broke, sending the entire load scattering across the concrete floor. Fortunately, no one was injured.

The preferred method of applying test weights to the scale is to use large block weights with chains of sufficient length and strength and "come alongs" in the appropriate capacity and quantity to apply the known test load to the load-receiving element. The better systems today have weights "permanently at the scale." Some also incorporate hydraulic cylinders for lifting the weights.

In addition to the larger test weight and equipment outlined above, it is necessary to have small weights in increments down to one tenth of the scale division for error weight testing. It is also helpful to have enough small weights to be able to trim substitution loads to an exact value, as will be discussed in detail in the next section. For an official test, you also need the proper report forms, seals, tags, sealing, pliers, etc. It is also desirable to have a way to apply small weights to the load-receiving element. I have found that a small plastic bucket works well. It can be hung on one of the chains used for lifting test weights. One thing that is often omitted from an equipment list is NIST Handbook 44. It is a "tool" and is very important. You should not play the game without having the "rule book" handy.

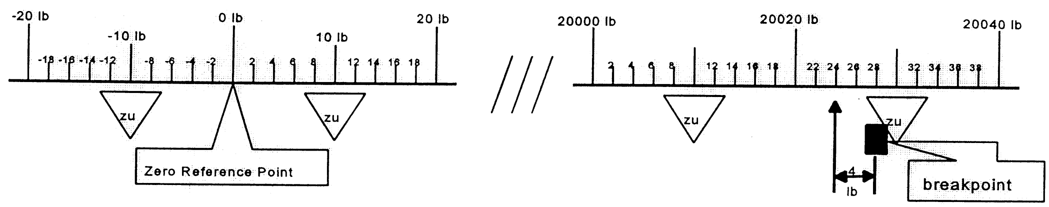
Terms to know.
Before discussing the actual test, it is necessary to discuss some terms used in hopper scale testing and explore their meanings, specifically, error weight testing, substitution testing, and strain load testing. *"Substitution tests"* and *"strain load tests"* may be used independently as separate tests of a scale; they may also be used in combination in the testing of large capacity hoppers.

"Error Weight Testing".
Error weights are used to determine the amount of error at a particular test load more accurately than can be determined from reading the indicator directly. On a mechanical beam scale, some small weights in increments equal to one tenth of the scale division can be applied to the load receiving element prior to establishing the zero load balance. Additional small weights can be used to re-establish a balance condition for the beam with the poise seated in the notch on the beam related to the applied test load. By using error weights the actual error of the device at a given test load can be determined to a more precise value than the smallest division of the beam. For example, the smallest division on the beam may be 20 lb. At a given test load if there is an error and the beam is not balanced, moving the fractional poise by 20 lb in either direction may be too much to establish a balance condition. With error weights added to or removed from the scale, the beam may be brought to an exact balance condition, and the actual error can be

determined based on the amount of error weights used to balance the scale. On an electronic device the principle is similar, but a little more difficult to visualize.

Digital Electronic Scales

Suppose that the test load has been increased to 20 000 lb and the scale indicates a stable 20 020 lb. The scale indication represents a weight between 20 012 and 20 028 (16 lb range) since the zone of uncertainty is 4 lb wide. Suppose that only 4 lb is needed to reach the breakpoint on the high end of the 20 020 lb division. This can be represented as

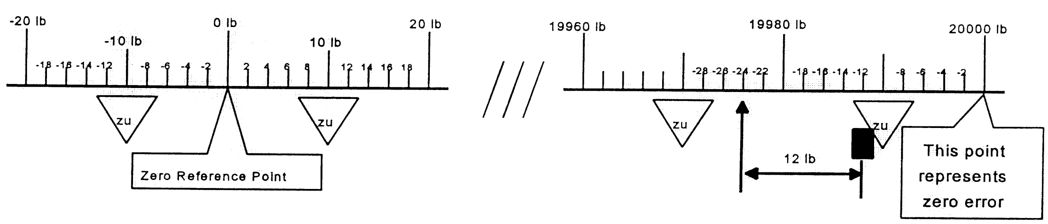


This scale error can be counted from the center of the 20 000 lb division to reveal an error of 24 lb. This is computed as follows:

Weight needed at zero to breakpoint		Weight needed at test load to breakpoint		indication error		scale error
8 lb	-	4 lb	+	20 lb	=	24 lb

Suppose that the scale indicates 19 980 lb and that 12 lb is needed to reach the breakpoint. The scale error is computed as: 8 lb - (122) + (-20 lb) = -24 lb.

This can be verified on the diagram as:



Notice in these examples that weight is always added to reach the breakpoint on the high end of the display division. For simplicity, this is the only method described. This method of calculation is valid even if the indication error is more than one division.

(figure of error weight testing on digital instrument using break point)

Once a good zero has been established, small weights can be used to bring the indication into the zone of uncertainty between zero and the first scale division. If six pounds is required from zero to have the indicator alternate between zero and an indication of 10 lb, this becomes the breakpoint for this particular device. Handouts are available from Dick Suiter at: phone (301) 975-4406, fax (301) 926-0647, email rsuiter@nist.gov.

"Substitution Test".

In a substitution test, material, product, vehicles, or other objects are substituted for known test weight on the load-receiving element of the scale, then the known test weights are again placed on the load-receiving element. For example, a load of 4 000 lb of known test standards may be applied to the load receiving element. The error is determined as accurately as possible using error weights. Once the error has been determined, the test weights are removed and product or material is placed in the hopper until exactly the same reading (including error weights) is established; again, error weights are used to determine the reading as closely as possible. If the reading of the indicator is exactly the same, including error weights, for both the known test weights and the substituted material, in effect the actual weight of the substituted material is the same as that of the known test standards, irrespective of any scale error at that point. The limitation on accuracy of this technique is the uncertainty of the error weight process and the readability of the scale. It is important to reduce that uncertainty as much as possible. Some of the sources of uncertainty are a change in zero balance, shift in load distribution, load cell creep, and the ability to achieve an exact substitution for known test weights.

On a beam scale, as mentioned earlier, it is best to start with some small weights balanced on the scale load-receiving element at zero. This allows the determination of errors in both directions using error weights. At the 4000-lb load with the poise set at the 4000 lb graduation, small weights are added or removed until the beam is in balance. The difference in small weights from the original starting point is the scale error at that point. When the system has a digital indicator a "balance condition" is not available, so an alternative method must be used to establish a reference point. One alternative is to use the breakpoint as a reference point.

In the earlier example, the weight required to get to the breakpoint was six pounds. To determine the error at a 4000 lb known test load and an indication of 4000 lb, the breakpoint is found using small weights. Any difference in the amount of weight required to reach the breakpoint and the original six pounds is the scale error at that point If the starting indication is not 4000 lb, the error in the indication must be included. For example, if the indication is 3990 (on a 10-lb division scale) and the amount of error weights required to arrive at the breakpoint for that indication is 4 lb, the actual scale error at that point is minus 8 lb. Keeping track of error weights to determine actual errors can be confusing and some practice is required. Using a diagram with the division broken down into tenths, such as shown on the figure may help.

The substitution process can be repeated several times to arrive at a larger "test load." The Office of Weights and Measures recommends no more than three substitutions due to the uncertainty of the process. Particularly when only direct reading of errors is used (not using error weights and breakpoints), the uncertainty may approach the tolerance applied to the scale. Because of this uncertainty, it is necessary to apply at least 25 percent of capacity in known test weights. If that is not possible, strain load procedures should be used after three substitutions.

"Strain Load Testing".

In strain load testing, the scale is tested using known test weights up to the amount of available weight. Then material or product is added to the hopper to some higher reading; in this case the true weight of the material is not known. For example, 5000 lb of known test weight can be used along with the substitution test procedure to test a scale up to 20 000 lb. If the capacity of the hopper is 60 000 lb, however, a strain load test must be used to test the device to a point near or at its capacity.

To perform the strain load test in this example, material can be added to the hopper until the reading is 55 000 lb. At this point, error weights are used to determine a starting reference point using the procedures described earlier for error weights. Once the starting reference point is determined, the 5 000 lb of known weight is added to the scale and the scale reading is determined at that point (60 000 lb) using error weights. The difference between the starting reference point and the ending reference point is compared with the 5000 lb of known weight to determine the error at 60 000 lb. In this case, the tolerance is based on the 5000 lb of known weight and not the 60 000 lb value. The major difference and drawback to strain load testing is the fact that there is no way to determine the scale's performance between the 5000 lb of known weight and the strain load of 55 000 lb.

The Test.
Now that everyone has at least some understanding of substitution and strain load testing we can proceed to review a complete test.

As with any scale examination, the first part is the inspection. During this phase the inspector will look at zero indication as found, suitability and appropriateness of design, correct installation, accessibility for testing (often this is a problem for older hoppers, particularly with respect to application of adequate test weights), marking requirements, and anything else required in the specifications section of Handbook 44. In an NTEP State, this also includes a determination that the scale and significant components are covered by an NTEP Certificate of Conformance. If only the load cells and indicator have Certificates of Conformance, this does not meet the requirements for an NTEP device. The load receiving element (hopper) must also have a Certificate of Conformance.

Next are the pretest determinations for the device under test. The inspector considers items discussed earlier, including capacity and division size, test loads to be applied, and the tolerances for those test loads.

The actual test is next. Ideally, the test will use known test weights to at least 25 percent of capacity and substitutions to the capacity of the device. If that is not possible, strain load testing may need to be incorporated. Regardless of the method used, the actual errors at the various test points will be determined and recorded.

Finally, once the actual performance of the scale has been determined, it will be evaluated as to whether or not any errors are within tolerance. Appropriate action based on compliance with requirements can then be taken.

Summary.
The test procedures for hopper scales are not much more difficult than those for many other devices. The most difficult and time consuming task can be the process of obtaining the necessary amount of known test weights and the process of applying

weights to the load receiving element. Proper installation of new devices which include on-site test weights can aid immensely in that regard. For older devices, the addition of proper permanent test weights, where possible, can pay off in labor savings as well as increasing scale accuracy and reliability. The keys to a successful hopper scale test are having the right equipment for the test to be performed, knowing how to do them, and understanding how to interpret the results.